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Report

Structural Review of Existing Buildings

Confidential

Prepared for Palmerston North City Council

Prepared by Beca Limited

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Revision History

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Document Acceptance

Action	Name	Signed	Date
Prepared by	**Steve Kemp**		07-01-2019
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on behalf of	Beca Limited		

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1 Introduction

Beca Ltd (Beca) has been commissioned by Palmerston North City Council (PNCC) to complete a high-level structural review of 12 buildings randomly selected by PNCC from those designed by Kevin O'Connor & Associates Ltd.

This report covers the scope of our review and the findings of each building review. Comments on the design in relation to compliance with B1 (Structure) of the Building Code and associated New Zealand Standards of the time have been made and are noted for each building.

Recommendations following the findings have been made that cover these 12 sample buildings and the general trends that have been noted.

1.1 Scope of High Level Review

The objective of the high-level review is to establish, on reasonable grounds, the belief that each building is most likely compliant with the Building Code, B1 – Structure.

The review has been undertaken against the current code of the time of the original design. The sample buildings were designed and issued for Building Consent over a period between 2004 and 2012. The method of demonstrating compliance is B1/VM1 – Verification Method 1. VM1 documents the appropriate codes and standards to be used in the design of the structures to comply with B1-Structure of the Building Code.

In general, these codes and standards cover the materials and design approach used (structural steel, concrete, timber, etc.). The Loadings code NZS 4203 (cited up to 1 December 2008) and NZS 1170 after 1 December 2008.

As standard practice in the engineering community, the verification method is usually listed in the Producer Statement, PS1 – Design that accompanies the Building Consent documentation.

In this context 'high level' means to overview or to review only the key design decisions and results, without deliberately delving into the detail.

The scope of our review was:

- Review of the seismic design of each building's primary lateral load resisting structural system. This includes ascertaining the load paths for wind and seismic actions on the building.
- Review of the application of the appropriate loads and actions on the structure, determined through review of the calculations and comparison to the methods and procedures set out in the appropriate loadings standard of the time.
- Review of the design of specific materials (such as structural steel, concrete) against the appropriate materials standard of the time of design.
- Desktop review only and not including an inspection of the as-constructed buildings.

The High-Level Review included:

- The available documentation
- The design philosophy
- The adequacy of the design lateral loads adopted in the design calculations as defined by the appropriate standard
- Specified materials are consistent with materials used in the design
- Identification of the primary lateral load resisting system and critical elements of the system

- If acceptable levels of ductility detailing have been adopted in the design
- A brief report outlining our findings.

Upon commencement of the review work, the structural engineer for the sample buildings was separately notified of our engagement by PNCC and Beca. Throughout the review process Beca was in communication with the structural engineer to discuss the issues that were discovered.

1.2 Limitations

By 'its' nature, a high-level review does not include detailed calculations or analysis of the structures, nor does it involve a detailed seismic assessment (DSA).

Our review is based on the information provided to us by PNCC and does not include site visits to the buildings. The review does not necessarily identify all of the issues that may be present in the design or construction of the building.

The Engineer has, in most cases, responded to our comments. We have not reviewed responses in any detail.

Our review provides a qualitative assessment only.

1.3 Disclaimer

This report is of a defined scope and is for reliance by Palmerston North City Council only, and only for this commission. Beca should be consulted where any questions regarding the interpretation or completeness of our review or reporting arise.

2 Building Descriptions

Twelve buildings were selected by PNCC. Archive records for each building were retrieved and sent to us by PNCC. The selection of the buildings was intended to be a random sample of work by the structural engineer and covers an approximate time period between 2005 and 2012.

The 12 sample buildings reviewed are described in the following table:

Subject Building	Date of Design and Cited Verification Method	General Description of Building	Summary of Issues Found
15 Bennett Street	April 2005 B1/VM1 NZS 4203:1992 (as noted in engineer's response)	Steel portal frame building, with cross bracing to walls and roof in the longitudinal direction, precast concrete panels to parts of the perimeter and a slab on grade with pad foundations beneath portal columns.	Areas of potential non-compliance identified: ■ Precast concrete panels are acknowledged by designer to be undersized to resist out-of-plane loads ■ Some roof purlins are unlikely to be sufficient to support the defined ULS wind loads ■ Wall bracing insufficient to take the longitudinal lateral loads ■ Additional fly bracing to the rafters is expected to be necessary to meet ULS loads.
142 Botanical Road	March 2011 B1 (cited on Producer statement) Verification Method not specified NZS 1170	Foundation pad for a relocated flour silo	■ No significant issues of non-compliance raised or outstanding.
160 Fairs Road	Varies, November 2008 to February 2009 B1 Verification Method not specified NZS 1170 (cited in calculations)	Steel portal frame building with cross bracing to walls and roof. Precast panels to some perimeters. Slab on grade and piled foundations for portal frame columns.	Areas of non-compliance identified: ■ Potential capacity of transom beams and lack of fly bracing to resist the ULS loads ■ Precast panel out-of-plane capacity to resist ULS seismic loads ■ Application of the seismic loads and design of elements for ensuring non-brittle failure of elements.
171 Railway Road	Issued for consent October 2011 B1 Verification Method not specified NZS 1170 (cited in calculations)	Steel portal frame building with a mezzanine floor addition. Precast concrete panels to some perimeters and cross braced walls. Slab on grade and timber suspended mezzanine floor. Concrete piles beneath portal frame columns.	Areas of potential non-compliance identified: ■ Pre-cast concrete panel capacity to withstand out-of-plane ULS seismic loads ■ Transom beams undersized to withstand ULS loads ■ Mezzanine floor diaphragm capacity ■ Geotechnical and pile capacity ■ Upper level portal framing.
620 Tremaine Ave	July 2009 B1 (NZS 1170 cited on Producer Statement)	Small portable prefabricated structure by 'Moduloc' with modifications	■ Holding down bolt/connection arrangement not detailed in the consent documentation ■ Requires a site visit to determine as-built arrangement and justification of compliance.
946 Tremaine Ave	May 2012 B1 (NZS 1170 cited on Producer Statement)	Steel portal framed building with cross bracing to walls and precast concrete panels to rear wall. Slab on grade and piled foundations beneath portal frame columns.	Areas of potential non-compliance identified: ■ Perimeter transom beams capacity to withstand ULS seismic loads.
Shelly Street	Issued for Consent December 2007 Verification method not known. Review based on NZS 4203:1992	Steel portal framed building with cross bracing to walls and precast concrete panels to rear wall. Slab on grade and piled foundations beneath portal frame columns.	Areas of potential non-compliance identified: ■ Rafter members not fly braced ■ Unclear on how seismic loads have been derived and applied to the structure ■ Purlin design not allowing for local wind pressures ■ Issues with bracing capacity under seismic ULS loads.
University Ave (AKA Tennent Drive)	August 2005 B1 NZS 3604 cited in calculations	Single-storey timber-framed building generally in accordance with NZS 3604: Timber Framed Buildings. Slab on grade with concrete pad foundations.	Areas of potential non-compliance identified: ■ Large ceiling diaphragm including discontinuity across the building.
38 Mathews Ave	Issued for consent March 2010 B1 (NZS 1170 cited in calculations)	Single-storey steel portal frame building with low level precast concrete panels to the perimeter. Rod cross bracing to the longitudinal direction and roof.	Areas of potential non-compliance identified: ■ Purlin design not allowing for dominant openings and local wind effects ■ Capacity design procedures not followed and hierarchy of failure to prevent brittle failures not considered ■ Lack of fly bracing to columns and knee restraint to the portals.
27 Kelvin Grove	Issued for Consent July 2008 B1 (NZS 4203 cited in engineer's response)	Single-storey steel portal frame building with precast concrete panels to the perimeter. Rod cross bracing to the longitudinal direction and roof. Stepped duo pitched roofing.	Areas of potential non-compliance identified: ■ Purlin capacity under ULS Loading ■ Capacity design procedures not followed, and prevention of brittle failures not considered

Subject Building	Date of Design and Cited Verification Method	General Description of Building	Summary of Issues Found
			■ Some portal columns found to be under capacity in minor axis bending under ULS loading ■ Wall bracing post capacity insufficient to resist ULS wind uplift condition ■ Transom beam capacity to support the precast concrete panels for out-of-plane ULS seismic loads.
104 Kaimanawa Street	Issued for consent November 2007 B1 (NZS 4203:1992 cited in engineer's response)	Single-storey steel portal frame building with precast concrete panels to the perimeter rod cross bracing to the longitudinal direction	Areas of potential non-compliance identified: ■ Capacity design procedures not followed ■ The hierarchy of failure and prevention of brittle failures has not been considered ■ Fly bracing to rafters noted as deficient ■ Purlins and girts deficient in places due to local wind effect factors.
			■

3 Findings

Based on our high-level review and discussions with the structural engineer, we have a number of concerns related to the structural design of some of the buildings.

From the table, we have categorised each building based on the number and severity of deficiencies identified in the high-level review. Broadly, this is as follows:

No significant issues of non-compliance identified.

Potential deficiencies identified but the effect on the performance on the building of these is likely to be minor.

A number of potential deficiencies identified, and we recommend that additional structural assessments are undertaken to confirm the extent and impact of non-compliance.

3.1 15 Bennett Street

15 Bennett Street is a single-storey steel portal frame building with longitudinal rod cross bracing and pre-cast concrete perimeter panels designed in 2005.

A number of potential issues have been identified for the building:

- Soil Class C adopted rather than D
- Roof purlins not designed for local pressure factors
- Dominant openings do not appear to have been accounted for
- Discrepancies in portal dimensions differing calculations and drawings
- No fly bracing to the portal knee joints
- Roof bracing appears to be deficient
- Eaves beam design is deficient
- Wall bracing, RB25 rods are deficient
- Precast concrete panels to the perimeter are deficient
- RC columns supporting the concrete panels are deficient
- Pile supports and ground beams have insufficient flexural capacity
- Transom steel beams are deficient
- Portal frame design is based on ductility 3.0 and no elastic design for other elements (bracing connections, etc.) has been undertaken as per the code of time.

The structural engineer responded to our initial notes with a large package of calculations and analysis, including acknowledgement that the majority of the issues raised are valid.

Our recommendation is that a detailed structural assessment of this building be undertaken to confirm the expected impact of these issues.

3.2 142 Botanical Road

This building consent is for a new foundation pad for a relocated silo structure.

The documentation was brief and, subject to a query on the seismic coefficient used for the derivation of seismic loads. Our review found no further issues with this consent.

We recommend no further action is necessary.

3.3 160 Fairs Road

Designed in 2008, Fairs Road is a steel portal framing building with longitudinal rod cross bracing and pre-cast concrete perimeter panels.

Based on the high level review the following potential issues were noted:

- Soil Class C used rather than D
- No parts and portions loading used for seismic design of panels
- Unclear on capacity of rafters and knee to portals with no fly bracing
- Roof bracing does not appear to account for the full seismic load area of the building
- The design of the portal frames, bracing and connections does not appear to have followed the provisions in NZS 3404: Steel Structures Standard for non-ductile/elastic design of key components.

The structural engineer responded to the queries raised and while some of the items have been addressed with additional calculations, a number of these issues are not resolved.

Principally, the differing opinion relates to the approach adopted for establishing the seismic non-ductile elastic design loads for the bracing and connections.

Our recommendation is that a detailed structural assessment of this building is undertaken.

3.4 171 Railway Road

This steel portal framed building was designed in 2011 under the current NZS 1170 Loadings Code. Potential issues noted in our review were:

- Pre-cast concrete panels under capacity to withstand out-of-plane ULS seismic loads
- Transom beams undersized to withstand ULS loads
- The mezzanine floor diaphragm capacity
- Geotechnical and pile capacity
- Upper level of portal framing.

The above issues have been addressed and acknowledged by the structural engineer. In most cases, there is agreement that the issues raised are appropriate and will require further investigation. Calculations provided by the engineer have identified areas requiring strengthening of elements as well as site inspection to confirm the construction of elements where no calculations have been provided, for example, the floor diaphragm.

Pre-cast concrete perimeter panels have been noted as not complying with the parts and portions loading requirements of the loadings code.

The structure is constructed adjacent to a neighbouring building and there appears to be insufficient or no gap between the buildings to prevent pounding. The engineer acknowledges this issue and recommends a site inspection.

Our recommendation is that a detailed structural assessment of this building is undertaken.

3.5 620 Tremaine Avenue

620 Tremaine Avenue is a small portable prefabricated structure by 'Moduloc'. Holding down bolt connections and arrangements were not detailed in the building consent documentation.

The engineer has acknowledged the lack of information and agrees that a site inspection is

required to confirm what was constructed and if it achieves compliance.

3.6 946 Tremaine Avenue

Designed in 2012, 946 Tremaine Ave is a steel portal framed building with cross bracing and perimeter concrete panel walls.

Areas of potential non-compliance identified were the transom beams to the perimeter and connecting the pre-cast panels to the steel frame. From the calculations provided, they appear to be insufficient to withstand the ULS seismic loads from the concrete panels.

Although these items are potential non-compliant, based on our review, we consider their effect on the performance of the building is likely to be minor.

3.7 Shelley Street

Issued for Building Consent in December 2007, this is a single-storey portal frame building with precast concrete panels.

The high-level review identified a number of potential issues:

- Limited calculations found and no derivation of seismic loads
- The portal rafters do not have fly bracing to restrain the compression flanges
- Base plate design has not been carried through onto the drawings
- Low seismic coefficient implies ductility of 3.0
- Soil Class C rather than D has been adopted
- Purlins don't appear to have been designed with local pressure factors
- Purlin spacing differs between calculations and drawings
- Bracing Elements. It is unclear if the bracing elements and connections have been designed for elastic/overstrength loads. Concern that these could be designed for lower loads than code stipulates.
- Portal frame design does not include for seismic weight of precast panels
- Precast panels don't appear to be designed for parts and portions loading
- Design calculations for piles is incomplete
- Dead man anchor sizing on drawings differs to calculated sizes.

These issues have been communicated to the structural engineer and no response has been received.

Our recommendation is that a detailed structural assessment of this building is undertaken.

3.8 University Avenue (AKA Tennent Drive)

Generally, this new veterinary clinic structure has been designed in accordance with the non-specific design standard NZS 3604: Timber Framed Buildings.

The review identified potential issues with the wind loading including local effects for the following:

- Design of the canopy structure
- Lintel design
- Ceiling diaphragm.

Through additional calculations and further correspondence these queries were closed out except for the ceiling diaphragm issue.

Our recommendation is that PNCC review these issues with a building consent officer, as in our opinion the ceiling diaphragm does not comply with NZS 3604. We note however, that this review is best undertaken by a building consent officer with experience in the application of NZS 3604.

3.9 38 Matthews Avenue

38 Matthews Avenue is a single-storey steel portal framed building with low level perimeter concrete panels and rod bracing to the longitudinal direction and lightweight roof. It was designed in 2010 and to the latest Loadings standard, NZS 1170.

Potential issues identified were as follows:

- Purlin design not allowing for dominant openings and local wind effects
- Capacity design procedures not followed and hierarchy of failure to prevent brittle failures not considered
- Lack of fly bracing to columns and knee restraint to the portals.

The engineer acknowledges that the fundamentals of capacity design and the procedures in the loadings code and materials standards have not been adhered to, but notes that calculations provided demonstrate that these checks are not required.

Our recommendation is that a detailed structural assessment of this building be undertaken.

3.10 27 Kelvin Grove

27 Kelvin Grove is a single-storey steel portal frame building complete with precast concrete panels to the perimeter walls. The roof and longitudinal walls are cross braced with steel rods. The roof is of a stepped duo pitched lightweight construction. The building was designed in 2008 under the older Loadings standard, NZS 4203.

Areas of potential non-compliance identified were as follows:

- Issues with purlin capacity under ULS Loading
- Capacity design procedures not followed, and prevention of brittle failures not considered
- Some portal columns found to be under capacity in minor axis bending under ULS loading
- Wall bracing posts insufficient to resist ULS wind uplift condition
- Transom beams under capacity to support the precast concrete panels out of plane ULS seismic loads.

The issues highlighted above have also been reviewed and acknowledged by the design engineer. The engineer's response includes follow on calculations for existing and new members required to strengthen existing elements.

It is noted that capacity design procedures and the design of the precast panels under parts and portions loadings has not been followed as per the Loadings code, NZS 4203.

Our recommendation is that a detailed structural assessment of this building be undertaken.

3.11 104 Kaimanawa Street

104 Kaimanawa Street is a single-storey steel portal frame building with perimeter precast concrete panels. The walls are braced in the longitudinal direction with steel rods. The building was designed in 2007 to the NZS 4203:1992 Loadings Standard.

Areas of potential non-compliance identified were as follows:

- Capacity design procedures not followed
- The hierarchy of failure and prevention of brittle failures has not been considered
- Fly bracing to rafters noted as deficient
- Purlins and girts deficient in places due to local effect factors.

While the non-compliances noted have been acknowledged by the engineer, a number of them have not be closed out. We do not agree with the engineer's interpretation of the capacity design procedures and hierarchy of failure and hence consider these issues have not been sufficiently addressed in the design.

Our recommendation is that a detailed structural assessment of this building be undertaken.

3.12

4 Summary of Findings

In general, the majority of the buildings reviewed are single storey portal frame structures with pre-cast concrete panels to the perimeter. The subject buildings were issued for building consent between 2004 and 2012.

Potential non-compliances were noted, in the main, for the buildings designed to the older loadings code; NZS 4203:1992.

Typically, the following potential non-compliances were identified:

- Precast concrete panels not designed for the parts and portions loadings of the code.
- Transom beams supporting the panels due to incorrect derivation of loads on the panels and fixings.
- Lateral loads and capacity design procedures, including the prevention of brittle failure mechanisms have not been followed in accordance with the loadings code and materials standards.
- Bracing in the longitudinal direction is typically rod bracing and not designed in accordance with the capacity design procedures set out in the code.
- Wind loading with local effect factors have not been applied to the design of purlins and girts in some cases.
- Section of soil class for the Palmerston North area. This can have a significant effect on the seismic loading of the building.
- Lack of fly bracing to restrain portal rafters in a number of the buildings.

During the review, PNCC received correspondence from the structural engineer outlining a number of changes in the seismic assessment guidelines and the Building (Earthquake-prone) Buildings Amendment Act 2016 that came into force in July 2017. We note however, that the scope of this review was to assess the sample buildings in relation to compliance with the Building Code in force at the time of the design and the consent submission. The correspondence refers to seismic assessment to the current guidelines and therefore is not applicable to this review.

5 Recommendations

As noted above, we have completed high level reviews on the subject buildings and have identified a number of potential recurring and common issues.

Our recommendations for the buildings identified is that a detailed structural assessment be undertaken to determine the full extent of issues and non-compliances.

We have included within the appendices all the information provided to us by PNCC, as well as correspondence between us and the engineer during the investigation.

Appendix A

Information Provided to Us and Correspondence Logs